Improved Low Temperature Hydrophobic Si-Si Bonding Techniques

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The double-sided, double-gate insulated gate bipolar transistor (DIGBT) structure utilizes a second gate to control minority carriers and enable fast switching. The use of wafer bonding to fabricate a DIBGT removes the processing complications associated with processing both sides of the wafer. A DIBGT has been fabricated by low temperature hydrophobic wafer bonding and has been demonstrated as a method of improving the forward voltage drop – switching loss tradeoff by 40% as compared to a conventional IGBT structure (1).

It has been shown (2) that the silicon oxide present at the interface of a hydrophilic bonded silicon wafer pair significantly effects the current-voltage and capacitance-voltage characteristics of wafer bonded structures designed for minority carrier transport through the bond interface. Preparation for hydrophobic bonding removes this oxide layer. In order to fully process and package double-sided wafer bonded devices, the bond strength of the wafers has been empirically determined to be 800 ergs/cm^2 (3). Sufficient bond strength is attained by annealing the bonded wafers at 400°C for extended times. However, the annealed wafers show considerable formation of thermally activated voids.

The presence of the thermally activated voids degrades the device performance by reducing the breakdown voltage, and is reason to fail the device. A great deal of work to remove the thermally activated voids has been performed with limited success. It is generally believed that the voids are due to the desorbtion of hydrocarbons from the surfaces of the interface. These hydrocarbons break down and form CH_4, and other light gasses that migrate together to form the voids (4). Chemical treatments of the surface have been explored as a possible solution to the thermal voids (5). It is possible to remove these voids by annealing at 800°C (5), but this is not compatible with the processed and metallized device wafers used for double-sided IGBT fabrication process.

In this work, a variety of bonding parameters and surface preparations are explored in order to develop a robust bonding process that is free of voids and has sufficient bond strength to saw the wafers apart. Another approach explored in addition to varying temperature and vacuum settings is etching a grid into the bonding surfaces. This is to enable the thermally activated gasses that create voids to migrate to inactive locations in the wafer

A commercially available wafer bonding tool, EV501 supplied by Electronic Visions Group, was utilized for the bulk of the experiments. Wafers have been bonded in low vacuum of $5x10^{-5}$ mbar, with temperatures ranging from 25°C to 350°C. If hydrocarbons are responsible for void formation, a low temperature bake in vacuum should be sufficient to desorb them. Temperatures of 400°C or higher will break the H-Si bond, and oxygen in the atmosphere, even in high vacuum, will preferentially bond to the free silicon surface.

The result of this work is a set of processing parameters that greatly reduce the number of thermally activated voids. Reducing problems associated with thermally activated voids makes possible the fabrication of reliable, high performance double sided devices using the wafer bonding technique.

References:

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